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PROCEEDINGS OF A WORKSHOP TO ESTABLISH CANADIAN MARINE OIL SPILL RESEARCH AND DEVELOPMENT PRIORITIES

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SUMMARY

This report presents the results of a two-day workshop, sponsored by the Environmental Studies Research Funds, which focused on the research requirements for improving the state-of-the-art for controlling major marine oil spills. Workshop participants included oil spill experts from Canada and other countries, and included those with industry, government, and consulting affiliation. The results of the workshop are a description and priority ranking of 77 research and development ideas within the five technical areas of : surveillance, tracking and modeling; containment and recovery equipment; dispersants; in-situ burning and disposal; and shoreline cleanup and restoration.

RÉSUMÉ

Ce rapport présente le compte-rendu d'un atelier de deux jours, parrainé par les Fonds d'étude en environnement, sur les recherches nécessaires pour améliorer les meilleures techniques de lutte contre les déversements importants d'hydrocarbures en mer. L'atelier a réuni des spécialistes canadiens et étrangers appartenant aux gouvernements, entreprises privées et cabinets d'experts-conseils. Soixante-dix-sept sujets de recherche et de développement sont décrits et présentés par ordre d'importance sous cinq rubriques spécialisées: détection, surveillance et modélisation des déversements; dispositifs de retenue et de récupération des hydrocarbures; dispersants; combustion in-situ et disposition des substances; et, nettoyage et remise en état des littoraux contaminés.

INTRODUCTION

A workshop was held in Ottawa, Ontario on March 6 and 7, 1990, to discuss and establish priorities for oil spill research and development (R&D) in Canada. The focus was on research requirements for improving the state-of-the-art for controlling major marine oil spills, both spills from tankers and from offshore drilling activities.

The Environmental Studies Research Funds (ESRF), a joint industry/government/public research funding program, sponsored the workshop with assistance from the Canada Oil and Gas Lands Administration (COGLA) and the Department of Indian Affairs and Northern Development (DIAND). A key objective of the workshop was to generate research ideas suitable for ESRF funding consideration. Organizations other than ESRF such as oil companies, industry oil spill co-ops, the Canadian Petroleum Association, Environment Canada, COGLA, DIAND, and the Panel on Energy Research and Development (PERD), all of whom were represented at the workshop, may similarly attempt to use the workshop results.

It is important to emphasize that the high priority projects identified at the workshop simply represent the results of several hours of discussion by the experts present at the meeting. The selected research ideas should not be considered definitive, all-inclusive, or applicable to every spill problem in Canada. **As such, the results of the workshop should be used selectively and with due regard for the limitations of a two-day meeting.**

WORKSHOP STRUCTURE AND METHODS

Approximately 45 oil spill experts from Canada and other countries were invited to attend the workshop; a limited number of non-experts with special interests in oil spill R&D in Canada were also invited. A total of 36 people participated in the workshop; of those 15 were from industry, 14 were from government and seven from the consulting industry (participating experts are listed in Appendix A). Several weeks before the workshop, invitees were asked to compile a list of R&D ideas that they

or their organization felt were high priority, and to have the list available at the workshop. No other pre-workshop demands were made, except that five persons particularly expert in key technical areas were asked to prepare short overview presentations, and were also asked to present their own ideas on oil spill R&D priorities for Canada.
The technical areas were:

- Oil Spill Containment and Recovery Equipment
- Dispersants and Other Treating Agents
- In-Situ Burning and Disposal
- Surveillance, Tracking and Modeling
- Shoreline Cleanup and Restoration

After each presentation, the floor was opened to allow questions and additional R&D ideas to be introduced. Each proposal was tagged by a descriptive title and listed on flip-chart sheets.

Two presentations were also made by representatives of industry operating in the Beaufort Sea and off the East Coast, outlining the nature of the spill problems in these areas and spill research that might be done to address the problems. New research ideas presented in these talks were added to the list. Finally, a presentation was made by a representative of the U.S. Petroleum Industry Response Organization (PIRO) on the multi-million dollar oil spill R&D effort that is now being proposed by PIRO.

After the presentations the long list of ideas was consolidated and the group broke into teams to discuss, prioritize, and develop the R&D ideas. Five teams were formed under designated team leaders, each to concentrate on one of the response/cleanup areas listed above (equipment, dispersants, burning, surveillance, or shoreline cleanup).

After the teams had sufficient time to discuss and prioritize the proposed R&D ideas, the leader from each team made a presentation to the whole group explaining the reasons for the team's ranking. This provided an opportunity for workshop participants to question the views of teams other than their own.

Following this group discussion, the teams re-formed to consider the comments of members of other teams and to expand upon and document details of the R&D projects that were considered finally to be high priority.

This ended the priority-setting exercise. There was no further attempt to rank the overall list of high priority projects because it was recognized that this ranking would vary depending on the "user" of the research. For example, those interested in tanker oil spills would have a different ranking than those interested in oil well blowouts, and those interested in Arctic oil spills might have a different ranking than those interested in spills in ice-free waters.

The meeting ended with a discussion of the need for various "users" of the research and potential research funding agencies (e.g., ESRF, Industry, Environment Canada, Canadian Coast Guard, PERD) to meet regularly to ensure that a co-ordinated effort was being made in the funding and execution of oil spill research in Canada.

WORKSHOP RESULTS

The following describes the R&D projects that were discussed and ranked by the five teams. The teams were asked to rank each R&D idea in terms of its potential for success and its potential for improving spill cleanup capability if the research were successful. The highest priority ideas were then to be fleshed out in terms of how the work would be conducted and the estimated time frame and costs of the work. Some teams had a limited number of proposed ideas to consider and were able to consider each idea in depth; others had a great number of ideas to evaluate and hence did not have the time to consider each in detail. Each team used a different approach in evaluating ideas, and this is reflected in the following summaries.

CONTAINMENT AND RECOVERY EQUIPMENT

Sixteen R&D project ideas on containment and recovery equipment and operations were proposed by the group at large and submitted to the "equipment" team for discussion and ranking. After discussion the following priorities were set.

High Priority

1. Develop standard test criteria for skimmers
2. Improve recovery of high viscosity products
3. Undertake comprehensive testing of skimmers
4. Develop standard test criteria for pumps
5. Investigate relation between boom performance and boom design and configuration
6. Investigate occupational health and safety concerns
7. Improve recovery of oil in ice
8. Evaluate use of special-purpose skimming vessels
9. Undertake comprehensive testing of pumps

Medium Priority

10. Improve capability to recover viscous oil in nearshore situations
11. Investigate coherent plunging water jets for oil containment
12. Develop comprehensive database for all spill equipment

Low Priority

13. Improve debris tolerance of oil recovery skimmers
14. Investigate recovery ideas that do not require fence-type barriers for containment
15. Develop higher capacity offshore skimmers to match the needs of very large spills
16. Investigate and develop operational systems to allow night-time recovery operations offshore.

Each project idea is discussed in turn.

1. Develop Standard Test Criteria for Skimmers: High Priority

Background: This project was considered to be the highest priority of all containment and recovery ideas proposed. The team felt that the most important problem related to existing recovery equipment is that standard criteria are not available for testing devices, and that great uncertainty exists over the absolute and relative merits of various devices. As such, informed and justifiable decisions on skimmer acquisition cannot be made, and defensible contingency plans can neither be specified or evaluated. Previous initiatives in this area include the extensive boom and skimmer testing carried out by OHMSETT (now mothballed, but reactivation is currently proposed) which reported independent test results under a fairly uniform set of test conditions. As well, ASTM has published standard definitions for measuring a skimmer's recovery rate and efficiency.

Proposed Work: The objective of this project would be to develop a standardized evaluation process and reporting format for oil recovery skimmers. Key performance criteria to be established would include recovery rate and efficiency measured at specified (i.e., oil viscosity, sea conditions relative forward velocity).

The project could be spearheaded by a task force of experts within Canada, who would ultimately liaise with international counterparts and particularly ASTM. Consultation with prominent users (i.e., Canadian and U.S. Coast Guard, key response co-operatives), skimmer manufacturers, and OHMSETT staff (if reactivated) is also recommended.

The likelihood of success of this project was considered to be high. As proposed it could be carried out over a period of one year or less at very low cost, perhaps in the range of $50,000.

2. Improve Recovery of High Viscosity Products: High Priority

Background: This project was considered to be a very high priority by the team in that a serious deficiency exists with the current capability to recover highly viscous products in the offshore regime. Recent spills of highly viscous fuel oils and of crude oils that rapidly emulsify have reinforced the need for skimmers that can process large volumes of viscous product.

Proposed Work: The team recognized this to be a subject of recent and ongoing research and development that should continue to be supported. Future work should include examination and evaluation of existing concepts and devices, as well as promising proposals.

3. Undertake Comprehensive Testing of Skimmers: High Priority

Background: This project was considered to be a very high priority, and a logical second step after standard test criteria (priority #1) are completed. Without these two projects, the oil spill response community is left with performance data that is a mix of manufacturer's claims, non-standard experimental data, and anecdotal information. Better data is required by both industry and government in order to adequately prepare for spill response, both for contingency planning and equipment procurement.

Proposed Work: Following the completed development of standard test criteria, a comprehensive testing program should be initiated including both test tank and field experiments. Such a program would likely require the establishment of a centre for tank-testing, either within Canada or in conjunction with a reactivated OHMSETT, and one or more centres for periodic field testing. The latter could be done in conjunction with existing depots of Coast Guard and/or industry co-operatives.

4. Develop Standard Test Criteria for Pumps: High Priority

Background: The team recognized the fact that transfer pumps are an integral part of a complete containment and recovery system. The situation for transfer pumps is analogous to that of skimmers: in the absence of standard test criteria, uncertainty exists over the performance claims of many devices. A standard set of test criteria is required in order to make sound decisions on contingency planning and equipment procurement.

Proposed Work: The objective of this study would be to develop a standardized evaluation process and reporting format for recovered oil transfer pumps. Key performance criteria to be established would include pumping rates at specified conditions such as product viscosity and pumping head. The team recommended that this project be carried out in conjunction with priority project #1 (Development of Test Criteria for Skimmers) in consideration of the close parallels of the two projects and possible use of the same project team.

5. Investigate Relation Between Boom Performance and Boom Design and Configuration: High Priority

Background: Although considerable work has been done to test containment boom performance both in test tanks and in the field, little or no work has been done to investigate the relationship between boom performance and boom design, particularly regarding a boom's cross-sectional profile. Field experiences as well as manufacturer claims have suggested that oil loss mechanisms at the boom may be influenced greatly by the boom's profile at and near the waterline.

Proposed Work: It is recommended that a testing program be initiated to investigate the effect of the cross-sectional profile of a boom on its performance. Testing would be carried out in a flume and/or test tank, initially with several key boom products and ultimately including all boom designs in common use.

6. Investigate Occupational Health and Safety Concerns: High Priority

Background: Serious concerns were expressed as to the health and safety issues related to offshore oil containment and recovery operations. These concerns are particularly important when countermeasures activities include operators and vessels that have primary functions other than spill response.

Proposed Work: It is proposed that a study examine health and safety concerns in the context of a complete offshore response system (i.e., containment, recovery, transfer, storage, oil processing). Operational considerations would include examination of: safety of spill response personnel on supply vessels; equipment handling; processing of hydrocarbons; explosion hazards of recovered oil; health aspects of in-situ burning; and proximity to spill source (both blowouts and tankers).

7. Improve Recovery of Oil in Ice: High Priority

Background: Although in-situ burning has been identified as a promising technique for oil amongst close pack ice, a serious deficiency exists in the ability to deal with oil in moderate ice concentrations. In ice coverages between 2 and 6 tenths, neither conventional containment and recovery techniques or in-situ burning would be fully successful.

Proposed Work: It is proposed that oil recovery in ice continue to be a priority subject for research and development, and that activities in this area be coordinated with Norwegian counterparts who also have a strong interest and experience on this subject. Two devices at the prototype stage, the Wartsila/Lori system and the Foxtail system, should be evaluated. The evaluation team was not optimistic about other new ideas for recovering oil in ice, but felt that the subject area was important and that support should be given to any promising proposals.

8. Evaluate Use of Special-Purpose Skimming Vessels: High Priority

Background: Offshore oil recovery systems in Canada and elsewhere have been based largely on the concept of mounting skimming devices on vessels of opportunity, specifically offshore supply vessels (OSVs) and the like. While having obvious merits in terms of reduced capital cost and operational flexibility, the concept has some drawbacks, particularly in areas of low offshore marine activity. A second important concern is the limited storage capacity of most OSVs. It was proposed that the concept of special-purpose skimming vessels be revisited and evaluated for applicability to spills in Canadian waters.

Proposed Work: Several special-purpose skimming vessels have been put into service in the last few years, including those in Germany, the Netherlands, and the U.S.S.R. These and other such systems should be evaluated as to their overall response capability, compared with existing state-of-the-art "portable" systems, and assessed for their applicability to the Canadian scene.

9. Undertake Comprehensive Testing of Pumps: High Priority

Background: Currently reported performance data on pumps and transfer systems does not allow adequate evaluations and comparisons of various products. Such information is particularly important for operators who are concerned with viscous oils and emulsions, and for operational configurations that may bottleneck due to inadequate transfer capabilities. This project is proposed as a second step that would follow the development of standard test criteria for pumps (priority #4).

Proposed Work: Based on the standard test criteria that are to be developed, a comprehensive testing program for pumps is recommended. It is expected that testing would be undertaken on some sort of priority system to be determined by the study team.

10. Improve Capability to Recover Viscous Oil in Nearshore Situations: Medium Priority

The proponent of this idea noted that large offshore spills often become large nearshore spills, and that the current state-of-the-art for nearshore spill recovery has a capacity of less than 1 m^3/h. Other higher-capacity devices are generally limited in nearshore application by draft requirements. The evaluation team recommended an assessment of existing systems as a medium priority project.

11. Investigate Coherent Plunging Water Jets for Oil Containment: Medium Priority

This idea was proposed as a possible solution to containing oil in water currents greater than 0.7 knots (at which point conventional booms fail) and for situations where broken ice could damage conventional booms. While the idea has been evaluated to some extent in the past it has never been developed as an engineered, operational system.

12. Develop Comprehensive Database for all Spill Equipment: Medium Priority

The objective of this project would be to develop a comprehensive and easy-to-use database for oil spill equipment. Information on each product would include primary specifications, performance data, handling information, and support requirements. It was noted that the Canadian Petroleum Products Institute is presently developing such a database.

13. Improve Debris Tolerance of Oil Recovery Skimmers: Low Priority

This project was noted as being particularly important for nearshore spills where kelp may reduce skimming performance. It was rated as low priority given that several existing skimmers are highly tolerant of debris and that debris tolerance is largely a pumping problem.

14. **Investigate Recovery Ideas that do not Require Fence-Type Barriers for Containment: Low Priority**

This idea was proposed as a way of extending the operating limits of recovery operations. It was suggested that the present approach of containing oil for recovery will always be limited by water currents of 0.7 to 1 knot and seas of 1 to 2 m, and that fresh thinking was required to tackle the problem.

15. **Develop Higher Capacity Offshore Skimmers to Match the Needs of Very Large Spills: Low Priority**

This idea was proposed on the basis that existing recovery devices were an order of magnitude lower than required for very large offshore spills. Although rated low priority on its own this idea was incorporated into priority #8: evaluation of a special-purpose skimming vessel.

16. **Investigate and Develop Operational Systems to Allow Night-Time Recovery Operations Offshore: Low Priority**

Historically, offshore spill response operations have not taken place during night-time due to problems with vessel positioning and concerns over worker safety. The evaluation team suggested that this was simply an operational problem requiring no development work in that adequate ship-source illumination systems are presently available. However, the team recommended that aircraft mounted surveillance systems should be researched and developed to aid in the night-time positioning of vessels relative to the slick.

DISPERSANTS

Sixteen R&D project ideas on oil spill dispersants and other treating agents were proposed by the group at large and submitted to the "dispersant" team for discussion and ranking. After discussion the following priority breakdown was made.

High Priority

1. Develop more effective dispersants.
2. Develop protocols and tools for field effectiveness trials.
3. Field test emulsion inhibitors and emulsion breakers.

Medium Priority

4. Test and evaluate agents as they are developed.
5. Investigate injection of dispersant into oil well blowouts.
6. Develop improvements for ship-based mixing of treated oil slicks.
7. Investigate dispersant effectiveness on very thick oil slicks.
8. Develop improved dispersant-use decision-making systems for Canada.
9. Investigate possibilities of adding emulsion inhibitors to crude oil shipments.

Low Priority

10. Develop solidifying agents to gel oil in-situ in stricken tankers.
11. Develop dispersant application systems for self-help use by stricken tankers.
12. Develop customized dispersants for specific oils.
13. Investigate optimum time for applying dispersants following spills.
14. Investigate and select new toxicity tests for chemical agents.
15. Investigate operational/logistic systems for dispersant use.
16. Validate laboratory effectiveness tests.

Each project idea is discussed in turn.

1. Develop More Effective Dispersants: High Priority

Background: This project was considered by far the highest priority of all dispersant ideas proposed. The team felt that the single most important problem related to the use of chemical dispersants is that existing products are believed to be relatively ineffective on the range of oils likely to be spilled in Canada and even on relatively non-viscous spilled oil. This opinion of Canadian experts is based in part on extensive analysis by Environment Canada of historical experimental and actual spills in which chemical dispersion was attempted.

Environment Canada has recently carried out an in-house program to develop more effective dispersant products and claims some success in this. The IKU organization in Norway has also been involved in developing more effective products, and also claims some success.

Proposed Work: A major international effort is proposed to develop more effective products. This could involve leading surfactant chemists from the major oil companies, detergent manufacturers, universities, and government laboratories. The level of effort required is proposed to be approximately $7 million over a period of seven years. The steps involved would be:

- identify international surfactant experts who could strongly contribute to the program, and host an international workshop (perhaps in Canada) to: review the state-of-the-art; identify problems in existing products; review product development efforts in Canada, Norway and elsewhere; brainstorm possible solutions; and initiate a preliminary work program for the international effort.
- develop performance criteria for new products including toxicity standards, effectiveness criteria, etc.
- conduct an intensive study to understand the physio-chemical mechanisms related to the effective dispersion of marine oil spills
- develop peer-reviewed effectiveness tests for dispersants that are validated by field tests (see next project idea)
- develop new formulations that are tested to be effective according to the developed performance criteria.

The likelihood of success for this project was considered medium; that is, the research is relatively risky. On the other hand, if the project proves to be successful, vast improvements in the state-of-the-art for dealing with offshore spills could be anticipated.

2. Develop Protocols and Tests for Field Effectiveness Trials: High Priority

Background: The measurement of how effective dispersants are when used on spills in the field, either real or experimental spills, is crucial in terms of product development, contingency planning, and environmental impact assessment. Techniques to measure effectiveness in past field dispersant trials, such as in-water sampling, surface sampling and remote sensing, have proved to have serious shortcomings. It is necessary to develop experimental protocols and analytical tools that can reliably measure dispersant effectiveness in the field, at least in controlled experiments. The system to measure dispersant effectiveness should be relatively inexpensive (involving fewer vessels, personnel and laboratory analysis than in previously used systems) and should provide reproducible results. Without good field data on dispersant effectiveness, smaller-scale effectiveness tests cannot be validated, and product development cannot proceed in a rational manner.

Proposed Work: The steps to be done in the proposed work are:

- systematically analyse previous field trials
- define parameters for determining dispersant effectiveness in the field
- research and specify tools for measuring dispersant effectiveness (and develop new tools as required; e.g., remote sensing system for measuring slick thickness)
- specify how tools will be used and how data analysis will be accomplished
- test and validate system on small scale, then in the field
- conduct feasibility study for extending test for use in real spills.

The likelihood of success for this proposed project was considered to be high. The costs were estimated to be approximately $800,000 over three years.

3. Field Test Emulsion Inhibitors and Emulsion Breakers: High Priority

Background: Research over the past five years has indicated that certain chemicals can be applied to marine oil spills to inhibit the oil's tendency to form viscous water-in-oil emulsions and even to break emulsions once formed. Laboratory, small-scale and a limited number of field trials have indicated that this can be done in concentrations less than 500 to 1000 ppm (one or two parts chemical to 1000 parts oil). The attractiveness of using these so-called emulsion inhibitors and emulsion breakers is that natural dispersion of the oil is improved over the untreated oil situation, physical recovery rates are potentially enhanced (because skimmers deal with less viscous and less voluminous product) and the window of opportunity for using chemical dispersants on the oil is greatly extended. Because only very low concentrations of inhibitor/breaker chemical are required, chemical handling requirements and overall logistical support are much reduced as compared with the use of existing dispersants. However promising the idea, the concept is new and has not been thoroughly examined and evaluated.

Proposed Work:

- define circumstances in which emulsion inhibitors and emulsion breakers could be used
- conduct an assessment of the previous work done in Canada and Europe regarding product formulations, laboratory testing and field testing
- assess the limitations of techniques with respect to oil type, environmental conditions, inhibition times, etc. and propose how these limitations could be addressed (e.g., through better products, increased dosages, etc.)
- conduct further controlled field tests if necessary
- research and develop appropriate field application systems and protocols for such chemical treating agents
- utilize products at appropriate spills of opportunity and assess results of application
- refine application systems and protocols as necessary

The likelihood of being able to develop products that work at least under a limited range of situations is considered good. The cost of the proposed work, assuming existing products are adequate and no further controlled field experiments are required, is about $200,000.

4. Test and Evaluate Chemical Agents as they are Developed: Medium Priority

As new oil spill treating agents are developed, there is a need (by government) to test and evaluate these at least on a comparative basis. This is important in order to ensure that only safe products are approved for use in the field, and to provide guidance to operational personnel who want information on the most effective products that are commercially available.

Although this project is considered to be a necessary government function, it was not given top priority because it does not directly improve the state-of-the-art, but simply fulfils a regulatory and information management requirement, albeit an important one.

5. Investigate Injection of Dispersant into Oil Well Blowouts: Medium Priority

The idea here is to inject dispersants into the well-head of a blowing oil well. If this could be done and the chemical were able to mix with the flowing oil in the gas/water/oil mixture, the oil entering the water environment would be immediately dispersed into the water column thus preventing surface oil pollution. Preliminary research in this area has been conducted in Norway.

This research idea was not given a high priority for a number of reasons. Some evaluators felt that highly-engineered Blowout Preventors (BOP), into which the dispersant would be injected, should not be tampered with because such tampering (if permitted by drilling engineers) would somehow reduce the safety of such equipment; others believed that if such an injection line could be engineered, it might as well be used to pump materials into the well to stop its flow; and finally others felt that the dispersant would not necessarily mix well with the oil in the three-phase flowing fluid.

6. Develop Improvements for Ship-Based Mixing of Treated Oil Slicks: Medium Priority

If a marine oil spill is treated with chemical dispersants using a ship-based application system, experience has suggested that the addition of mechanical mixing energy to the treated oil will enhance dispersion of oil into the water. A common approach is to use a "breaker board" system (such as that developed at the U.K. Warren Springs Laboratory (WSL)) in which wooden slabs are towed over the treated oil. Research sponsored by ESRF has showed that high pressure water jets are much more efficient than the WSL breaker board system for accomplishing enhanced dispersion. It was proposed at the workshop that further research and development of this high pressure water system should be conducted.

Another idea proposed at the workshop for enhancing the dispersion of chemically treated oil was to research the possibility of towing containment boom downstream of the treated oil. The boom would be towed in a failure mode (> 1 knot) thus forcing the treated oil to flow to several metres below the surface, where, it is hoped, it would remain in tiny droplet form.

Both ideas are based on the contention that poor dispersant effectiveness may be due to inadequate mixing energy at the water surface: that natural forces on their own may not be sufficient to drive treated oil into the water column and that additional mixing energy may be generally required to effect this.

Neither idea was considered to be of high priority. Reasons given by the evaluation team were: that it has not be conclusively demonstrated that additional mechanical mixing energy actually enhances long-term dispersion; that ship-based dispersant systems have limited utility compared with aerial systems; that more research should be done to understand dispersant effectiveness in natural mixing situations before studying mechanical mixing to improve natural mixing; and, finally, that it is higher priority to first develop more effective dispersants than to attempt to improve the effectiveness of existing products through better application/mixing methods. In other words, first improve dispersant effectiveness through better formulations, then investigate how these better formulations can be used more effectively with better application systems, added mixing devices, etc.

7. Investigate Dispersant Effectiveness on Very Thick Oil Slicks: Medium Priority

It is known that large batch spills at sea are composed of a relatively thick portion of oil surrounded by a much larger area of very thin sheen. At the beginning of a very large spill the thick portion can be several centimetres thick. Although spreading occurs rapidly, the thick portion may still be several millimetres thick many hours after the accident. The proponent of this idea suggested that this thick oil should be the target for dispersant application. Previous field dispersant trials, involving small volumes of oil, necessarily involved relatively thin slicks in the 0.1 mm range. Such relatively thin slicks do not simulate the situation at large spills and, based on field trials experience, have been shown to be difficult to disperse with existing products. It was suggested that dispersant applied to thick layers of oil (i.e., several millimetres thick) would have a greater opportunity to mix thoroughly with the oil, and thus promote better dispersion as happens with oil pre-mixed with dispersant.

This idea was not considered high priority by the expert evaluators, most of whom were not convinced of the logic of the idea. In addition, as with the previous idea, the general view was that existing dispersant products could and should be improved substantially before secondary studies on dispersant effectiveness are contemplated. Even if thick slicks are more dispersible than thin slicks, there is a need to develop better formulations, and once this is done, studies on slick-thickness effects could be considered.

8. Develop Improved Dispersant-Use Decision Making Systems for Canada: Medium Priority

Before dispersants can be used to treat marine oil spills, government approval is required at the time of the spill. The decision must consider environmental trade-offs between the effects of leaving the oil on the surface versus the effects of dispersing the oil into the water. For very large spills the trade-off decision is inherently difficult because many resources and factors must be considered, and must be considered quickly before the oil weathers to dispersant-resistant viscosities. Rigorous dispersant-use decision making systems are not available in Canada except in the southern Beaufort Sea, where a system was developed in the mid-1980s with funding from ESRF. This system was used as a

basis for developing a sophisticated, computerized system for the U.S. Gulf of Mexico. It was proposed that this computerized system be developed for various high risk areas of Canada.

This proposal was not supported as high priority by the dispersant team. One reason given was that the transport of the Gulf-of-Mexico system to Canada would involve little research and development inasmuch as the system is already functional. Another reason given was that the major issue currently associated with dispersant-use decision making is not ecological concerns but concerns over dispersant effectiveness, which should be given top priority. Once the effectiveness issue is resolved, more attention can be directed toward environmental impact considerations.

9. Investigate Possibilities of Adding Inhibitors to Crude Oil Shipments: Medium Priority

The potential value of using emulsion inhibitors was discussed earlier in reference to project No. 3 above. It was further suggested at the workshop that the ultimate use of such chemicals would be to pre-mix them into crude oil during the loading of tankers, especially in cases where the target oils (like Alaska North Slope crude oil) are known to emulsify very quickly once spilled. For this to be considered practical, the environmental benefits would have to outweigh the costs of the operation, which could exceed $20,000 per supertanker load.

This idea was not considered high priority because: a) it was felt intuitively that, considering the low probability of large crude oil tanker spills, the costs of routine addition of expensive chemicals to tanker cargos would be prohibitive; and b) there is still strong uncertainly regarding the effectiveness/utility of such chemicals. More research is required (as in Project No. 3 above) to confirm this before this project is initiated. The project idea was not rejected outright because if emulsion inhibitors are found to be truly important for oil spill response, then this idea (adding chemicals to cargos) represents a guaranteed method of ensuring that the chemical is properly mixed with the spilled oil.

10. Develop Solidifying Agents to Gel Oil In-Situ in Stricken Tankers: Low Priority

This idea, proposed many times over the past twenty years, is to add a solidifying or gelling agent to the contents of breached tanks following an oil tanker casualty, with the hope of solidifying the oil and preventing further outflow. The idea was rejected because past research in the U.S. has demonstrated that there are serious problems of thoroughly mixing extraneous chemicals into oil tanks, and that the chemical reaction time to effect solidification/gelling (many hours) far exceeds the time taken for oil to flow out of holed tanks (minutes to a few hours).

11. Develop Dispersant Application Systems for Self-Help Use by Stricken Tankers: Low Priority

It is generally acknowledged that dispersants should be used as soon as possible following an accident while the oil is relatively fresh and non-viscous. The idea proposed here is have dispersant and application gear on every crude oil tanker so that, in the event of a polluting accident, the tanker crew could apply dispersant to the discharging oil or to the oil that is on the surface but close to the vessel. This might be done by high pressure hosing from the deck or by the use of helicopters if such aircraft are available on board.

This idea was rejected for a number of reasons related to practicality. A previous study for Environment Canada on self-help countermeasures for Arctic oil tankers investigated the idea in some detail and rejected it mostly because of logistical/application problems. In addition, the idea would only have merit if dispersants could be shown to be effective on very thick pools of oil, and this is an uncertainty as discussed in Project No. 7 above.

12. Develop Customized Dispersants for Specific Oils: Low Priority

This idea was given low priority insofar as Canadian requirements are concerned. The concept of developing customized dispersant products for specific oils is based on the idea that every crude oil is unique chemically and may require unique dispersant agents for effective results. In countries where the crude oil of concern is predominantly one type (e.g., Norway) the development of customized dispersants makes sense. For countries like Canada where dozens of crude oil types are imported, the idea makes less sense because one would have to stockpile and have ready for use dozens of dispersant products. Another major concern with the idea was that it is premature. It was felt that the science of formulating chemical dispersants is rather primitive at present and requires more in-depth research and understanding prior to attempts at product customization.

13. Investigate Optimum Time for Applying Dispersants Following Spills: Low Priority

The idea behind this proposal was not perfectly clear to the evaluation team. Perhaps the thought was that one could delay the dispersant response to a spill, track the spill's movement, and then disperse only that part of the spill that was threatening key resources. Basically the idea was rejected because the expert opinion is that a dispersant response must take place immediately, that is, before the oil weathers to dispersant-resistant viscosities.

14. Investigate and Select New Toxicity Tests for Chemical Agents: Low Priority

The idea was to improve existing toxicity tests for treating agents to make the tests less expensive and time-consuming. It was reasoned that if a large effort is made to develop new formulations (such as in Project No. 1), there will be a need to streamline the toxicity-testing component of the development process. The idea was given a low priority because it was felt that existing tests, although not perfect, were more than adequate to deal with current and near-future requirements.

15. Investigate Operational/Logistic Systems for Dispersant Use: Low Priority

Although it was agreed that there is a need to develop appropriate logistical and application systems for dispersant-use in Canada, it was felt that the technologies existed and that little research was required to configure these for use in Canada.

16. Validate Laboratory Effectiveness Tests: Low Priority

This project was given a low priority as a separate project only because it was already included in dispersant-related Project No. 1, a designated high priority project.

IN-SITU BURNING AND DISPOSAL

Thirteen project ideas in the area of in-situ burning and eight ideas related to oil spill disposal were proposed by the workshop participants at large. The evaluation team categorized these as follows. Ideas within each priority category are listed in arbitrary order.

IN-SITU BURNING

High Priority

1. Conduct large-scale offshore burning trials using fire-proof/fire-resistant booms
2. Investigate the in-situ burning of water-in-oil emulsions
3. Investigate the effect of waves and currents on in-situ burning
4. Investigate novel methods to enhance the combustion of oil spills
5. Investigate in-situ burning of oil on mud flats
6. Develop protocols and procedures for conducting in-situ burning safely under different conditions
7. Develop regulatory/public information programs on in-situ burning

Medium/Low Priority

8. Conduct standardized oil containment tests for fire-proof/fire-resistant booms
9. Conduct meso-scale tests to determine feasibilities of burning uncontained oil
10. Investigate in-situ burning in broken ice conditions
11. Investigate the value of using emulsion breakers with in-situ burning

Low Priority

12. Develop simple smoke plume dispersion models for in-situ burning decision-making
13. Investigate the safety of operating helicopters in the vicinity of burning oil spills

DISPOSAL

High Priority

1. Develop specifications for oily material combustion systems for major spills
2. Conduct emissions testing of spill disposal kilns, incinerators and flares
3. Develop high-rate flare burners for offshore disposal
4. Develop pre-packaged pitliners for temporary storage
5. Review large-scale municipal/industrial waste management and other systems for applicability to spills

Medium/Low Priority

6. Scale-up kilns and sand washer systems for use on larger sediments

Low Priority

7. Develop containers for transportation of oily debris
8. Investigate the temporary storage and disposal of oily debris on ice

Each project idea is discussed in turn.

BURNING

1. **Conduct Large-Scale Offshore Burning Trials Using Fire-Proof/Fire-Resistant Booms: High Priority**

Successful in-situ burning of contained oil spills has been demonstrated in numerous laboratory, meso-scale and field tests. Large-scale offshore field trials are required to demonstrate the efficiency of the technique, to verify the results of the smaller-scale work, and to begin the process of developing

protocols and procedures for the safe use of in-situ burning and of educating regulators and the public on the merits and limitations of this approach to marine oil spill control. Such large-scale tests are now being organized by the U.S. Minerals Management Service, Environment Canada, and the National Institute of Standards and Technology. In these trials the current plan is to conduct tests with fresh oils in relatively calm conditions. This will allow the measurement of combustion efficiencies under ideal conditions and the analysis of smoke emissions in a rigorous fashion. As part of the program, attempts will be made to develop response protocols that will guide operational personnel in the safe application of in-situ burning under a variety of spill circumstances (see project idea no. 6 below).

The evaluation team agreed that following these experimental spills, further meso-scale and offshore trials will be required to evaluate the effectiveness of various proposed ignition devices and techniques, to test methods for residue recovery, and in general to evaluate the effectiveness of in-situ burning under non-ideal conditions and (for Canada) using Canadian East Coast waxy oils in a variety of weathered states.

2. Investigate the In-Situ Burning of Water-in-Oil Emulsions: High Priority

Certain offshore crude oil spills, depending on oil type, are known to emulsify quickly, so that by the time vessels and fire-resistant containment boom can reach the spills and set up operations, the oil may be in an emulsified state. It was proposed by some at the workshop that insufficient research work has been done on the burning of emulsions, and that large-scale tests to evaluate ignition potential and flame spreading were required to determine its feasibility. Others felt that preliminary research has indicated that emulsions basically do not burn on water and that offshore, large-scale tests are premature and too costly to consider at this time. It was agreed that it was important to resolve the issue, considering the likelihood of emulsion formation at most crude oil spills, but that the work should proceed first at the meso-scale level before moving into the field.

3. **Investigate the Effect of Waves and Currents on In-Situ Burning: High Priority**

Although there is a strong opinion that in-situ burning on calm and low-current waters is likely effective, there are uncertainties as to what the limitations are with respect to waves and relatively high currents. It was agreed that meso-scale tests in wave basins are required to understand and determine the extent to which waves and currents affect the efficiency of the combustion process.

4. **Investigate Novel Methods to Enhance the Combustion of Oil Spills: High Priority**

It was proposed that novel yet simple methods may be available, such as air injection and the use of steel wool heat-transfer promoters, to significantly enhance combustion rates and efficiencies for in-situ burning. Such methods could not only allow more oil to be consumed but might also reduce soot in air emissions. It was agreed that the idea was relatively easy to test as part of small-scale or meso-scale experiments conducted for other purposes (see above ideas nos. 2 and 3) and should be given high priority.

5. **Investigate In-Situ Burning of Oil on Mud Flats: High Priority**

It is generally understood that attempting to burn oil on most shoreline types is not recommended because the heat might increase the fluidity of the underlying non-burning oil, causing it to sink deep into the beach sediment. This is likely not to happen on mudflats, so it was proposed and agreed that in-situ burning might be an efficient method of oil removal in this case and should be pursued on a high priority basis.

6. Develop Protocols and Procedures for Conducting In-Situ Burning Safely Under Different Conditions: High Priority

Aside from issues related to effectiveness, the major concern over the in-situ burning of marine oil spills relates to the safety aspects of the operation. For spills that are close to either land, stricken tankers or offshore production and drilling facilities, there is a concern that burning oil could flash back to the origin of the spill or set fire to resources on land. There is also a concern, considered to be exaggerated by most experts, of serious health hazards associated with smoke emissions from burning offshore spills. In terms of flashback, the team's view was that simple methods, such as water hosing of slicks between the burning oil and resources at threat, can be used, in certain circumstances, to prevent unwanted spread of the fire. But the question is what are those certain circumstances, and how close to resources at risk and under what conditions should in-situ burning be permitted. It was agreed that such risk analysis was not necessarily straightforward, and that research and field testing had to be conducted to answer the key questions. Similarly, the air pollution issue is controversial and must be studied in a rigorous manner, and limits set on the use of in-situ burning where real health or environmental hazards can be identified. Finally, procedures must be developed for operational personnel to ensure that the most effective burning devices and equipment are used in the most efficient manner to attain maximum response capability. In several areas, information is lacking and research is required for making intelligent decisions. It was noted that developing operational guides for safe and effective in-situ burning is an objective of the upcoming U.S. trials and program (project no. 1). More research may be required in certain areas to establish operational strategies and safety procedures under a variety of spill and environmental conditions but should await the results of project no. 1.

7. Develop Regulatory/Public Information Programs on In-Situ Burning: High Priority

Developing public information programs on the in-situ burning issue is not an R&D function but the evaluation team believed it was important enough to include as a high priority activity.

8. **Conduct Standardized Tests for Fire-Proof/Fire-Resistant Booms: Medium/Low Priority**

A standardized test protocol is being developed for conventional offshore booms (by MMS) and this should be used to evaluate fire booms in the absence of fire to determine their capability and limitation with respect to oil containment.

9. **Conduct Meso-Scale Tests to Determine Feasibilities of Burning Uncontained Oil: Medium/Low Priority**

Preliminary research sponsored by MMS and Environment Canada suggests that uncontained oil at sea might be burned efficiently under certain conditions. The evaluation team felt that the concept has merit and is worth pursuing but not until other more important research is conducted on contained oil spills.

10. **Investigate In-Situ Burning in Broken Ice Conditions: Medium/Low Priority**

The issue of in-situ burning in ice conditions is important to both Alaskan and Canadian Beaufort Sea operators and it was agreed that there is a need to conduct tests over the entire range of ice coverage up to 9/10th ice. The proposed idea was not given a high priority simply because of the limited applicability of the technique (a few weeks per year) and the recognition that much is already known about burning oil in complete ice cover situations.

11. **Investigate the Value of Using Emulsion Breakers in In-Situ Burning: Medium/Low Priority**

This interesting idea is related to idea no. 3 in the dispersant area. The proposal is to use emulsion breakers to treat a spill that has heavily emulsified and then to burn the resulting free oil (this was dubbed the break-and-burn option). The questions are: Are emulsion breakers effective on

emulsions that are not ignitable? What are the limitations of in-situ burning of emulsions and would emulsion-breakers extend those limits? It was clear to the evaluation team that separate research on the effectiveness of emulsion breakers and of burning emulsions is first required before pursuing this research idea that combines both concepts.

12. **Develop Simple Smoke Plume Dispersion Models for In-Situ Burning Decision-Making: Low Priority**

It was felt that such dispersion models are already available.

13. **Investigate the Safety of Helicopters Operating in the Vicinity of Burning Oil Spills: Low Priority**

It was felt that this and other safety issues would be included in the "protocols and procedures" project (no. 6 above).

DISPOSAL

1. **Develop Specifications for Oily Material Combustion Systems for Major Spills: High Priority**

The evaluation team believed that before new disposal systems are researched and developed for major spill use it was important to review recent significant spills to identify the specific problems that evolved with respect to oil spill material disposal; the amounts, characteristics and locations of the materials requiring disposal; and the limitations of the various disposal methods and programs that were attempted. The objective would be to develop specifications for disposal systems for major spills that impact shorelines including consideration of equipment feed stock, throughput, transportability, etc. The team felt that once meaningful specifications were developed an overall disposal system could be

assembled using existing know-how and technologies. It was felt that the need is not to develop new technologies but rather to decide on the size, number and variety of existing systems that will be needed and to have these constructed beforehand or designed beforehand and ready for fast construction when a spill does occur. In addition, it should be ensured that any specified systems will be approved for use at the time of a spill.

2. Conduct Emissions Testing of Spill Disposal Kilns, Incinerators and Flares: High Priority

At the Valdez spill there were delays in establishing oily material disposal programs because proposed disposal systems apparently did not meet government air quality guidelines. The evaluation team felt that this could be avoided to some extent in the future if disposal systems including kilns, incinerators and flares were tested for emissions under a range of operating conditions including feed stock, throughput, method-of-operation, etc. The results of the testing could then be submitted to regulatory agencies for opinions on the acceptability of the systems for use at spills and for ideas on what pre-spill and spill-time actions would be required (by government or industry) to ensure that disposal operations at major spills are conducted in a planned and rational manner.

3. Develop High-Rate Flare Burners for Offshore Disposal: High Priority

The evaluation team agreed that there were obvious benefits of disposing of collected oil at the site of an offshore spill rather than transporting the oil to land for disposal there. Existing barge- or ship-mounted flare burners are known to require design improvements and it was felt that a serious R&D program should be undertaken to develop better and higher capacity flare burner systems for oil spill disposal offshore.

4. **Develop Pre-Packaged Pitliners for Temporary Storage: High Priority**

It was suggested that although technologies exist for constructing plastic-lined pits on land for the temporary disposal of collected oily material, there is a problem in acquiring appropriate liners in a reasonable time. It was proposed and agreed that pre-packaged liners should be designed and developed, along with specifications for pit construction, liner instaliation, and environmental controls.

5. **Review Large-Scale Municipal/Industrial Waste Management and Other Systems for Applicability to Spills: High Priority**

Waste disposal, solids handling, and liquid/solid separation processes in municipal/industrial applications are proven areas of technology. It was felt that much could be learned by reviewing such large-scale technologies to determine if any had applicability to the problem of oily material disposal at major spills. This idea is similar to the idea proposed in the shoreline cleanup area (project no. 5).

6. **Scale-up Kilns and Sand Washer Systems for Use on Larger Sediments: Medium/Low Priority**

Small-scale, low-throughput kilns and washing systems are available for cleaning oiled sands, and it was agreed there was a need to scale these up to deal with larger beach sediments such as pebbles and cobbles. The proposed idea was not given a high priority simply because work in this area is already underway by Environment Canada.

7. **Develop Containers for Transportation of Oily Debris: Low Priority**

The evaluation team felt that identifying containers for transporting oily debris was perhaps something that had to be done, but no serious research was required to do so.

8. Investigate the Temporary Storage and Disposal of Oily Debris on Ice: Low Priority

This proposed idea applies to Arctic spills in winter where collected oil and oily material would be stored temporarily on ice and dyked by an ice berm, and later ignited and burned. The evaluation team felt that this was a good but old idea that required little research. Most felt that there would be no problem in constructing such a containment area and in burning the oil.

SURVEILLANCE, TRACKING AND MODELING

Thirteen project ideas in this area were proposed by the workshop participants. The evaluation team ranked these as follows. Ideas within each priority category are listed in arbitrary order.

High Priority

1. Develop improved methods for displaying/presenting spill tracking data collected by remote sensing aircraft
2. Develop better methods for measuring oil dispersion (same as dispersant idea #2 above)
3. Investigate the behaviour of oil in broken ice in the presence of wind
4. Develop systems for measuring oil slick thickness
5. Investigate the use of CODAR for oil spill surveillance/trajectory modeling

Medium Priority

6. Develop sensitivity maps for high priority areas in Canada

Low Priority

7. Develop better models for the behaviour of oil under and on ice
8. Develop methods for detecting oil under ice
9. Investigate ship-based surveillance systems
10. Investigate the potential of subsea oil well blowouts to create emulsions
11. Study oil spill emulsification to predict mechanisms and rates of formation
12. Develop operationally useful oil spill property and behaviour models
13. Study spreading and surface diffusion of heavy and waxy oils

These are discussed in turn.

1. **Develop Improved Methods for Displaying/Presenting Spill Tracking Data Collected by Remote Sensing Aircraft: High Priority**

The current method of conducting aerial oil spill reconnaissance is to transfer imagery data, from UV/IR/LLTV sensors and visual observations, to a chart of the area being overflown. In order to cover vast areas, aircraft must travel at speeds in excess of the observer's ability to collate this information with navigational data. Accordingly, there is a requirement for a system that integrates the aircraft's position with sensor data. Ideally this would produce a presentation to which observers could add other points of interest. The objective would be to return from a flight, and with a minimum of processing, produce a chart depicting areas where oil has migrated. To capitalize on aircraft of opportunity, the device, to the extent practical, should either incorporate its own navigational instruments or be able to tap into those of the aircraft. The project was viewed as being highly feasible with current technology. The concepts not only would have practical application, but some commercial potential. For these reasons it was rated the team's highest priority.

2. **Develop Better Methods for Measuring Oil Dispersion (Same as Dispersant Idea #2 Above): High Priority**

This proposal is identical to idea no. 2 in the dispersant area. (It was included in the surveillance group because the 1986 Beaufort Sea dispersant field trial utilized remote sensing as a tool for measuring oil lost from the surface as an index of dispersion.) As discussed earlier, work with oil spill dispersants in the field has been seriously hampered by the lack of a reliable assessment of amounts of oil dispersed in the water. Various techniques have been tried, such as discrete sampling/laboratory analysis, flow-through U/V analysis, radioisotopic tracers, and remote sensing, but none of these has produced definitive, reliable results. It was felt that the only other avenue that held some promise would be the development of sonar techniques, first attempted during the 1983 Halifax dispersant field trial.

3. Investigate the Behaviour of Oil in Broken Ice in the Presence of Wind: High Priority

Although much is known about the behaviour of oil on and under an ice cover, little is known about the behaviour of oil in broken pack ice especially in the presence of winds. An ESRF-sponsored experimental oil spill in pack ice conditions off Cape Breton in the mid-1980s produced some useful information but more work is required in this area.

4. Develop Systems for Measuring Oil Slick Thickness: High Priority

A large offshore oil spill is usually composed of a very large surface area of thin sheen and a much smaller area of thick oil representing most of the oil spill volume. In surveillance operations it is important not only to distinguish between thick and thin portions of the spill but also to estimate the thickness (or area and volume) of the thick portion. This is important for response, fate-predicting, and environmental impact assessment purposes. Ideally, it would also be desirable to determine the water content of the oil and its viscosity.

At present, no satisfactory system exists for measuring the volume or thickness of marine oil spills. For large spills that cover vast areas, aircraft-based measuring systems are required. A major R&D program supported jointly by the U.S. Minerals Management Service (MMS), Environment Canada, and Esso Resources Canada is currently underway to develop such remote sensing systems.

The subject was accorded a high priority in view of its operational importance. However, the R&D currently in progress is assessing those technologies that appear to have potential. Accordingly, from a funding point of view this project may not be ranked as high.

5. **Investigate the Use of CODAR for Oil Spill Surveillance/Trajectory Modeling: High Priority**

CODAR is a device/technology for measuring surface currents from a remote land-based location. Inasmuch as the lack of accurate information on surface currents is the most important shortcoming in predicting the trajectory of marine oil spills, it was recommended that CODAR technology be pursued and exploited on a high priority basis for adaptation to spill modeling. It was suggested that the instrumentation may require reconfiguration in order to be used aboard aircraft, should this degree of portability be beneficial.

6. **Develop Sensitivity Maps and Countermeasures Manuals for High Priority Areas in Canada: Medium Priority**

Oil spill sensitivity maps of some sort are available across Canada. Generally they were developed in the 1970s in hard-copy, are not standardized, not easily updated, not easy to use and understand by anyone but the specialists who are very familiar with them (and whose availability during spills is not assured), and generally not well suited for use during a major spill in which adaptation and changes to the maps, and overlays with oil spill locations, must be accomplished on a regular basis.

The modern approach to sensitivity mapping is to use computerized geographic information systems, of which there are dozens on the commercial market. Computerized oil spill sensitivity mapping programs are currently underway in the Arctic, on the west coast of Canada, and to some extent in other areas. Unfortunately, a repeat of past errors in hard-copy mapping may be occurring in that the mapping systems being developed are not standardized or interchangeable, and may not be appropriate to meet the needs of a major spill, as was the case for initial systems utilized at the Valdez spill. At the workshop the evaluation team recognized the need for a standardized sensitivity mapping system in Canada and for developing new approaches other than standard atlases for spill response purposes. However, it was not clear to the evaluation team whether sensitivity mapping was an R&D issue. The project was therefore accorded a medium priority for action.

7. Develop Better Models for the Behaviour of Oil Under and on Ice: Low Priority

Although the behaviour of oil on and under an ice cover is not completely understood, it was felt that numerous studies conducted in the past in this subject area have provided much information for contingency planning purposes. This matter was given a low priority since further work in this area would not provide a basis for altering oil spill countermeasures plans.

8. Develop Methods for Detecting Oil Under Ice: Low Priority

The evaluation team felt that the requirement for systems to detect oil under ice was high but that much research has already been conducted in this area, dating from the early 1970s. A prototype system has been developed and is now available. The prototype, developed jointly be Environment Canada and Esso Resources Canada, is an acoustic device that relies on the change in viscosity between water and oil and is capable of producing up to ten soundings per hour. Thus, further research was considered to be a low priority because a detection system, albeit with limited operational capability, already exists.

9. Investigate Ship-Based Surveillance Systems: Low Priority

The evaluation team could not appreciate any practical advantage in pursuing the concept of ship-based spill surveillance given the low speed of surface vessels. Even though novel sensor packages such as vessel-towed balloons could be imagined, their value in practical terms was felt not to warrant investigation.

10. Investigate the Potential of Subsea Oil Well Blowouts to Create Emulsions: Low Priority

A subsea oil well blowout model is available and used extensively in Canada in contingency planning work for East Coast and Beaufort Sea oil and gas offshore drilling. The model, based on research in Canada and Norway and on data available from the Ixtoc-1 spill in Mexico in 1979, predicts the at-source dimensions of a spill from a subsea blowout. The major uncertainty is whether the at-source surface oil from all subsea blowouts will be in the form of a water-in-oil emulsion, as was the case of Ixtoc-1. If the answer is that only emulsion will be available at the site of a subsea blowout then the use of chemical dispersants must be ruled out for use. If the oil remains unemulsified at-source then ship-based chemical dispersion offers a practical solution to the problem. It has been suggested that emulsion was immediately formed at Ixtoc-1 largely because of the intense oil/water mixing at the surface, the high oil evaporation due to the heat from the burning gas, and perhaps the nature of the spilled oil. The high mixing was likely due to the extremely high oil and gas flow rate and the shallow water depth. Whether emulsions will form during non-burning, low-flowrate blowouts in deeper waters and with the oils being discovered offshore Canada is open to conjecture.

The evaluation team did not consider this to be an immediate area for Canadian research because Grand Banks crude oil is waxy and not condusive to dispersion by surfactants. In the Beaufort Sea, two other countermeasures approaches, namely in-situ burning and physical recovery, are already felt to be adequate to handle blowout spills.

11. Study Oil Spill Emulsification to Predict Mechanisms and Rates of Formation: Low Priority

Complex oil spill fate-and-behaviour models are available, and one such model is used extensively for contingency planning in Canada. It was suggested by some at the workshop that such models are useful in helping regional operational personnel develop countermeasures techniques and purchase equipment that can deal with the specific nature of spills in their area of responsibility. Existing models do not predict water-in-oil emulsification rates with a high level of certainty, so it was suggested that research was needed to fill the gap. The operational value of this research would be the

ability to predict the circumstances under which dispersants and in-situ burning might be selected for use on Canadian spills, considering that these two techniques have low or no effectiveness on spills after stable emulsification occurs. The evaluation team did not accept the premise that a predictive model represented an operational advantage since the emulsification process usually occurs faster than the capability to respond. Instead the team felt there was value in conducting basic research to understand the physical/chemical processes by which water-in-oil emulsification occurs.

12. Develop Operationally Useful Oil Spill Property and Behaviour Models: Low Priority

As with the previous project idea, the evaluation team questioned the operational value of oil spill behaviour models, and gave this proposed idea little consideration. One observation was that they have not proved to be accurate predictors of actual spill behaviour and are simply an arbitrary description of oil spill processes that are only of value at the planning stage.

13. Study Spreading and Surface Diffusion of Heavy and Waxy Oils: Low Priority

This idea was given a low priority again because it was not considered to have operational value.

SHORELINE CLEANUP AND RESTORATION

Eleven project ideas in the area of shoreline cleanup were proposed by the workshop group as a whole. Most were judged by the "shoreline cleanup" evaluation team to be either high or medium priority, as listed below. Ideas within each priority category are listed in arbitrary order.

High Priority

1. Improve oil spill contingency plans in Canada for shoreline cleanup
2. Review, screen and bench-scale test biotechnology/biodegradation techniques
3. Enhance transfer of existing knowledge to operational personnel
4. Conduct field evaluations of selected shoreline cleanup techniques

Medium Priority

5. Assess technologies from other industrial sectors for applicability to shoreline cleanup
6. Review and evaluate existing state-of-the-art in shoreline cleanup
7. Modify or fine-tune existing technologies as required, and field test
8. Investigate surficial nucleation
9. Monitor the persistence of stranded oil at existing cold climate spill sites and predict self-cleaning rates
10. Conduct full-scale tests of promising bio-enhancement techniques

Low Priority

11. Design barge-mounted shoreline cleanup and disposal system

Each project idea is discussed in turn.

1. Improve Oil Spill Contingency Plans in Canada for Shoreline Cleanup: High Priority

Background: Present oil spill contingency plans in Canada are deficient in presenting details on planned shoreline cleanup activities, especially those related to the long-term requirements of a major, protracted spill. The objective of this high priority project is to develop an improved generation of oil spill contingency plans and an overall improved state of preparedness for shoreline cleanup.

Proposed Work:

- First, develop the data and information base necessary for use in shoreline cleanup contingency plans, and then provide guidelines for the development of such plans ensuring that the following subjects are dealt with:
  - the use of standardized terminology
  - community training
  - organization of volunteers
  - public and media information requirements
  - occupational health and safety requirements
  - simulated exercises
  - environmental and socio-economic sensitivity criteria
  - framework for interagency decision making
  - processes for the provision of expert advice, such as the SCAT (Shoreline Cleanup Assessment Team) concept.

2. Review, Screen and Bench-Test Biotechnology/Biodegradation Techniques: High Priority

Background: The use of microbiological degradation is often considered for restoration of oil contaminated shorelines, yet it is a poorly understood process. A number of products and techniques have been promoted for use at the Valdez spill but these have not been evaluated. The objective of the proposed project is to assess the scientific validity and applicability of current information related to bio-

enhancement and biodegradation of oil on shorelines, and to take the first steps in considering the use of such techniques and products on future spills in Canada.

Proposed Work:

- critically review all literature and previous studies on the bio-enhancement and biodegradation of oil on shorelines, and any other relevant biotechnology applications
- investigate and clearly establish the role of the technique or techniques as an oil spill response option
- develop a procedure for the bench-scale testing of biotechnology/biodegradation techniques and materials at a screening level
- develop criteria for the approval of materials/techniques for use in Canada (this activity has already been commenced by Environment Canada)
- conduct bench-scale tests on existing materials and techniques

3. Enhance Transfer of Existing Knowledge to Operational Personnel: High Priority

Background: There is already a substantial body of information available on acceptable and effective methods for shoreline cleanup, but no systematic programs have been developed in Canada to transfer this information to operational personnel.

Proposed Work:

- review and assemble existing knowledge on effective and ecologically-sound methods for cleaning up oil-contaminated shorelines
- develop manuals and other documentation for users incorporating:
  - information on shoreline types, processes, and sensitivities
  - information on oil-shoreline interactions as a function of weather, oil type, loadings, etc.
  - guidelines on how, when and why to clean shorelines
  - limitations and applications of specific techniques

- occupational health and safety aspects of specific techniques
- develop programs to train users
- establish a continuing program to update manuals and guides as new information becomes available

4. Conduct Field Evaluations of Cleanup Techniques for Pebble-Cobble Beaches: High Priority

Background: Pebble/cobble and mixed sediment beaches are a common shoreline type in Canada but their cleanup after spills has not been efficient. There is a lack of hard data on the effectiveness and effects of different techniques, and on the criteria needed to select and apply methods that are best for the environment. A series of relatively small-scale experiments were proposed by the evaluation team to address the critical deficiencies in cleanup and disposal capabilities.

Proposed Work:

- identify promising techniques worthy of further research and development
- conduct controlled field experiments to quantitatively evaluate promising, ecologically-sound techniques for cleaning pebble/cobble shorelines contaminated with crude or bunker oils. The experiments should investigate:
  - effectiveness of the various techniques
  - effects caused by cleaning techniques
  - ecosystem recovery rates vis-a-vis different techniques
  - comparison of results to no-clean option
  - methods for dealing with driftwood and seaweed
- Note: initial scoping studies for such work have been recently completed by Environment Canada and further feasibility studies are in progress.

5. **Assess Technologies from Other Industrial Sectors for Applicability to Shoreline Cleanup: Medium Priority**

The proposal is to investigate the application of existing/emerging technology from other industrial sectors to problem areas in shoreline cleanup, in particular the removal of subsurface oil residues. This investigation could spawn subsequent work on adaptation and testing of any new, promising technologies.

6. **Review and Evaluate Existing State-of-the-Art in Shoreline Cleanup: Medium Priority**

This proposal is simply to review existing literature, documented experiences and studies on shoreline cleanup. The work would include an assessment of the scientific validity and practical value of existing quantitative information with reference to the effectiveness of different techniques and constraints on their use.

7. **Modify or Fine-Tune Existing Technologies as Required, and Field Test: Medium Priority**

This proposal, a follow-up to the previous one, is to modify or fine-tune specific existing technologies and techniques for shoreline cleanup where there is potential and need for improvement, and to conduct quantitative effectiveness testing where there is a known deficiency in data. Specific technology areas would include washing, chemical treatment and in-situ burning, methods for handling driftwood and log studded beaches, and other areas identified in the assessment as having deficiencies. Consideration would be given to satisfying oil spill need based on scale and location. (Note that two such individual projects are in progress by ESRF and Environment Canada.)

8. **Investigate Surficial Nucleation: Medium Priority**

Physio-chemical enhancement by surficial nucleation is a natural mechanism whereby oil on shorelines is gradually removed by fine particulate matter that may be present in local coastal waters. There is a need to develop an experimental protocol and to conduct bench-scale testing to better understand this process and assess its role with respect to oil spill cleanup. This work could lead to a subsequent requirement for field-scale evaluations.

9. **Monitor the Persistence of Stranded Oil at Existing Cold Climate Spill Sites and Predict Self-Cleaning Rates: Medium Priority**

The proposal is to revisit existing cold-climate spill sites to monitor the long-term fate and persistence of the stranded oil and the recovery of the affected beaches. The objective is to collect data for improving the capability to predict impacts and self-cleaning rates and to assess appropriate cleanup actions to take, if any, for future spills. Note that studies conducted under this topic must produce a consistent, reliable database.

10. **Conduct Full-Scale Tests of Promising Bio-enhancement Techniques: Medium Priority**

This proposal follows from project idea no. 2 above. The intent would be to conduct full-scale field testing and evaluation of the most promising techniques and materials for bio-enhancement and biodegradation of oil on shoreline using experimental oil plots representing different shoreline types/oil spill scenarios.

11. Design Barge-Mounted Shoreline Cleanup and Disposal System: Low Priority

This proposal is to identify applicable components of existing technology and prepare recommendations on design and methods-of-use for barge-mounted, large-scale shoreline cleanup and disposal scenarios. It was judged to be low priority from a research perspective.

APPENDIX A

ATTENDEES AND EVALUATION TEAMS AT OILSPILL R&D WORKSHOP

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